

# A Magnetron Sputter Deposition System for the Development of Multilayer X-Ray Optics

Completed Technology Project (2013 - 2014)



## Project Introduction

The proposal objective is to establish the capability to deposit multilayer structures for X-ray, neutron, and EUV optic applications through the development of a magnetron sputtering deposition system. A specific goal of this endeavor is to combine multilayer deposition technology with the replication process in order to enhance the MSFC's position as a world leader in the design of innovative X-ray instrumentation through the development of full shell replicated multilayer optics. The development of multilayer structures are absolutely necessary in order to advance the field of X-ray astronomy by pushing the limit for observing the universe to ever increasing photon energies (i.e. up to 200 keV or higher); well beyond Chandra (~10 keV) and NuStar's (~75 keV) capability. The addition of multilayer technology would significantly enhance the X-ray optics capability at MSFC and allow NASA to maintain its world leadership position in the development, fabrication, and design of innovative X-ray instrumentation which would be the first of its kind by combining multilayer technology with the mirror replication process. This marriage of these technologies would allow astronomers to see the universe in a new light by pushing to higher energies that are out of reach with today's instruments. To this aim, a magnetron vacuum sputter deposition system for the deposition of novel multilayer thin film X-ray optics is proposed. A significant secondary use of the vacuum deposition system includes the capability to fabricate multilayers for applications in the field of EUV optics for solar physics, neutron optics, and X-ray optics for a broad range of applications including medical imaging.

The proposed activity involves the development of multilayer structures for the enhancement of optical instrumentation for the field of X-ray, EUV, and neutron optics applications. One of the final outcomes would be the marriage of multilayer technology with MSFC's replication process and the developing differential deposition process to produce full shell, high-angular resolution-multilayer mirrors. To this aim we are seeking funding for: the design, acquisition, and assembly of a magnetron sputter deposition system for the development of novel multilayer thin film X-ray optics. The system would be designed in such a way as to provide the flexibility in deposition geometry and motion control needed for the development of multilayer coatings on various substrates including deposition directly on mandrels needed to produce full shell replicated optics which is a key component for enhancing the performance of X-ray space telescopes.

Multilayer X-ray mirrors are nanometer scale structures consisting of alternating layers of high and low refractive index materials. Multilayer structures are advantageous due to the large selection of materials whose unique optical and mechanical properties can be exploited for the design and optimization of reflectivity over a much broader range of photon energies than single layer total reflection optics which is currently utilized by Chandra, for example.



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The large number of layers and the means to precisely control their thickness combined with advances in optimization algorithms has recently extended their application to broadband-type X-ray optics. These so called aperiodic or depth graded multilayers can be tailored to elicit a specific spectral reflectivity response over a particular photon energy range of interest.

Magnetron sputtering is a technique for depositing thin films (i.e. nanometer scale thickness). This deposition process requires a magnetic field behind a target of material from which the films are composed. Atoms of a gas, such as argon, will become ionized as a result of the interaction with a high density of electrons trapped close to the target surface by the magnetic field. Atoms of the target material are ejected due to the collisions of the gas ions which have been accelerated due to the Coulomb force between the negatively charged target surface and the positively charged gas ions. These atoms are ejected by momentum transfer and then effectively evaporated onto a smooth substrate thereby forming a film of pure material which can be as thin as a few atomic layers thick. A vacuum environment is required to ensure: a large mean free path, purity of the sputtered species, and purity of the gas used as the source of ions. The large and diverse selection of material compositions including compounds, dielectrics, and metals that can be sputtered by this technique is a distinct advantage over other methods such as thermal evaporation

## Anticipated Benefits

The ultimate goal is to provide the X-ray astrophysics community with improved instrumentation for the discovery of how the Universe works from the very moment of its creation through the evolution of galaxies, stars and planets, how it will continue to evolve, and what its ultimate fate may be.

This proposal is specifically related to the following technology theme: X-ray telescope systems and associated technologies.

This proposed activity will also stimulate the, neutron, EUV, and X-ray instrumentation development in other fields including medical imaging.

## Organizational Responsibility

### Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

### Lead Center / Facility:

Marshall Space Flight Center (MSFC)

### Responsible Program:

Center Innovation Fund: MSFC CIF

## Project Management

### Program Director:

Michael R Lapointe

### Program Manager:

John W Dankanich

### Project Manager:

Andrew Keys

### Principal Investigator:

David M Broadway

### Co-Investigators:

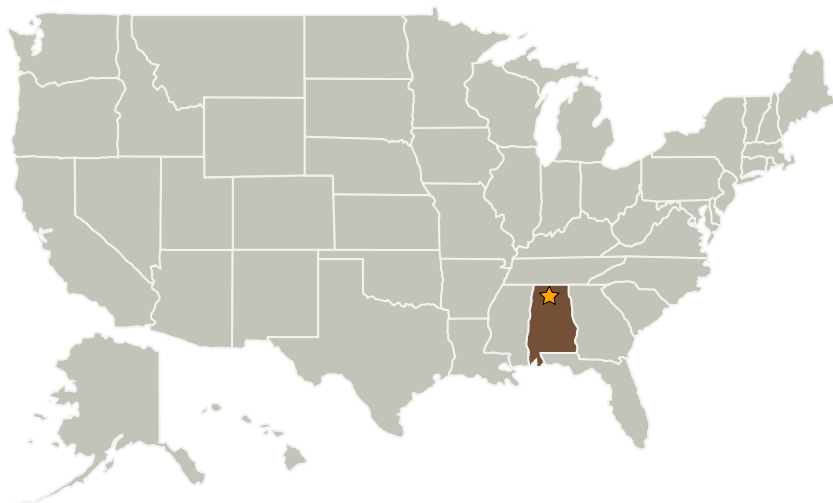
Mikhail V Gubarev  
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## Primary U.S. Work Locations and Key Partners



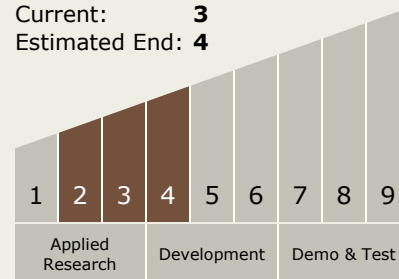
Organizations Performing Work	Role	Type	Location
★ Marshall Space Flight Center (MSFC)	Lead Organization	NASA Center	Huntsville, Alabama

## Primary U.S. Work Locations

Alabama

## Technology Maturity (TRL)

Start: **2**  
 Current: **3**  
 Estimated End: **4**



## Technology Areas

### Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - TX12.4 Manufacturing
    - TX12.4.3 Electronics and Optics Manufacturing Process